2012 Space Human Factors Engineering Standing Review Panel

Research Plan Review for:
The Risk of Inadequate Human-Computer Interaction

Final Report

I. Executive Summary and Overall Evaluation

The 2012 Space Human Factors Engineering (SHFE) Standing Review Panel (from here on referred to as the SRP) participated in a WebEx/teleconference with representatives from the Human Research Program (HRP) Space Human Factors and Habitability Element and HRP management (list of participants is in Section VII of this report) on November 16, 2012 to review the Research Plan for the Risk of Inadequate Human-Computer Integration (HCI) in the Human Research Program's (HRP) Integrated Research Plan (IRP Rev. D).

In general the SRP thinks that the SHFE Project had prepared a very good and very thorough presentation. The SRP thinks that the HCI gap revisions represent a significant improvement over previous versions. Particularly important are the explicit descriptions of how the gap will be considered closed, and the steps to reach gap closure. It also is very useful to have an explicit statement of how an individual task will mitigate or partially mitigate the risk though this was not listed in every task and doing so is recommended. Information about how an individual task relates to other tasks and how the task is integrated with other HRP Elements also is valuable. Overall, with the exception of the lack of detail provided for the unfunded tasks, the information is easier to understand and evaluate compared with previous versions.

The SRP also thinks that the new classification of gaps into Definition Gaps, Knowledge Gaps, Requirements Gaps, and Mitigation Gaps is a valuable addition.

Overall, the SRP thinks that there are too many critical tasks that are unfunded. The SRP realizes that there are budgetary restrictions and that the SHFE Project cannot control this but it is important to emphasize that the lack of funding for critical tasks contributes to risk. It is not clear to the SRP how the tasks were prioritized and whether prioritization was based primarily on risk. Perhaps the classification of gaps could aid in this prioritization.

The interim steps in each gap are assigned a percentage to help track how much progress has been made in closing the gap. As an initial attempt, the percentages were evenly divided over the number of steps and don't really represent how much time each step will take. It is not clear which steps depend on the others. In general there is no sense of a critical path to closing the gap. Also, steps that are done should be marked "DONE".

Tracking progress definitely has merit, but the SRP questions the validity of the percentages and the SRP is not sure how time-to-completion estimates were derived. For example, these estimates could be influenced by amount and consistency of funding, and requirements for equipment or human participant data.

Perhaps an alternative would be to assign values to the steps that represent relative weightings of

importance in closing the target. If one step is more critical than another, it would get a higher weight (regardless of how long it takes to complete). This would seem to be more associated with progress toward gap closure and may also help with the prioritization of tasks. It would also be good to set the interim steps on a Gantt chart to show dependencies and the critical path.

II. Critique of Gaps and Tasks for the Risk of Inadequate Human-Computer Interaction

Gaps and Tasks:

SHFE-HCI-01: What are the effects of vibration and acceleration on crew task performance and how can those effects be mitigated?

- The SRP thinks this is a relevant gap.
- The gap and the target for gap closure are well defined and lead to an approach with a closure measures (% complete) that should enable a mitigation strategy. The questions of the interim steps form a methodical technical approach that should produce a mitigation capability.
- The SRP thinks that this gap is a good model for the rest of HCI.

Task:

- Robust Human-System Interface Design for Spaceflight-Induced Environments – PI: Lee Stone, Ph.D., NASA Ames Research Center
  - This task was closed in 2012 with vibration effects noted and will not be redone unless it is anticipated that vibration effects will be greater than what was looked at in the study.
  - The SRP thinks that there seems to be some overlap with this task and a task in SHFE-HCI-03 (Information Presentation – Displays Development (Visual and Auditory)) which is completed. Clarity in this regard would be helpful.

SHFE-HCI-02: We need to understand what aspects of cognitive function change during long-duration missions and how this affects task performance.

- The inclusion of "quantitative effect sizes" as a target for gap closure is excellent and is worthy to consider including as a target for all gaps. Quantitative predictions of effects will be more effective at closing the gap than qualitative predictions.
- The SRP is concerned that this depends on mining the planned database and soliciting research on attention/cognitive load task performance during multitasking, situation awareness, and task complexity. Capturing low level data (e.g., keystrokes) produces much data but it is extremely difficult to infer high level intent without some input by the end users. Capturing audio and video will certainly help but the SRP thinks there was concern about user privacy which will certainly not be possible if audio and video are captured. Also, if capture is focused only on those things where end users are working on the computer, much in the way of planning, discussions, problem solving, etc. may well be missed. The SRP would like to have more details on the plans for this data capture and analysis. Will there be a way to capture discussion and actions not supported by computing?

Tasks:

- Effects of Attention and Cognitive Load on Long-Duration Task Performance – Planned task
  - The SRP thinks this is a critical task that is necessary to reduce risk, but it is UNFUNDED.

SHFE-HCI-03: We need HCI guidelines (e.g., display configuration, screen-navigation) to mitigate the performance decrements identified in SHFE-HCI-08 due to the spaceflight environment.

- For the target for gap closure, the SRP thinks it would be helpful to know what is intended for the nature of the guidelines and how they will be disseminated and used.
- The SRP thinks the target for guidelines seems appropriate, quantifiable, and feasible, but the SRP does not think the interim steps form an approach that will hit the target.
- The SRP recommends restating the interim steps as questions (as in SHFE-HCI-01), then reconsidering the planned tasks. Defining information needs will be a key early step. SHFE-HCI-06 should feed these tasks.
- SHFE-HCI-07 is now part of this as well. The SRP would like to know who pulls all these results into guidelines that do not currently exist and who does the case study to validate the new guidelines.

Tasks:

- Advanced concepts for information integration and presentation – Planned task
  - The SRP thinks that the aim for this task is vague in terms of presenting trending information and non-visual modality (assuming auditory modality).
  - Is it known from the literature whether this would be the most effective approach, and how exactly to present the information to maximize comprehension of data? Also, how does this type of presentation mitigate *physiological* effects of long-duration spaceflight?
  - The first item is the basic step of literature review, but it is not targeted until 2018 which is too distant in the future.
- Advanced multi-modal solutions for alerting and directing – Planned task
  - The SRP does not understand why this task will focus on alerting. What is the context and how does this fit into the gap? What performance decrement is it addressing? Is it alerting/directing for emergencies and warnings or routine tasks?
  - The SRP thinks that there seems to be some overlap with another completed task (Information Presentation – Displays Development (Visual and Auditory)) which also deals with alarms.
- Information Presentation - Electronic Procedures and Fault Management – Task completed
- Information Presentation – Controls Technology Survey and Testing – Task completed
- Information Presentation – Displays Development (Visual and Auditory) – Task completed
- Information Presentation – Human Performance Modeling – Task completed
- Sensorimotor Displays and Controls to Enhance the Safety of Human/Machine Cooperation During Lunar Landing – PI: Laurence Young, Ph.D., Massachusetts Institute of Technology

- Displays and Controls Interfaces – PI: Aniko Sandor, Ph.D., NASA Johnson Space Center
- Enhancement of Spatial Orientation Capability of Astronauts on the Lunar Surface – PI: Rongxing (Ron) Li, Ph.D., The Ohio State University
- Modeling and Mitigating Spatial Disorientation in Low G Environments – Task completed

The SRP felt that for many of these proposed tasks, without more coherent interim steps and detailed aims, it is difficult to evaluate whether the tasks will be relevant and sufficient to produce the needed mitigation capability.

SHFE-HCI-04: We need to understand how emerging multi-modal and adaptive display and control technologies are best applied to the design of HCI for proposed long-duration DRM (Design Reference Missions) operations.

- The SRP thinks that this gap and the target for gap closure are not defined enough to plan a set of interim steps that will produce the needed capability. The interim steps will need requirements for the implied evaluations (i.e., what gap does the new technology need to close?).
- This gap proposes "continuous monitoring" of new technologies, but the SRP is unsure how watching for new technologies will help close the gap? The SRP thinks that the technologies would have to be tested and evaluated in the context of specific mission tasks.
- It is unclear how this monitoring will be done, where the information will come from, and who will do the "continuous" monitoring.
- With respect to the closure for this gap, the SRP thinks that at some point in time, you just have to stop, because the time does not permit any more research to be incorporated into the research plan, or for human performance to meet acceptable risk limits.

Tasks:

- Tech Watch for Improving HCI in Next-Generation Missions – Planned task
  - The SRP thinks that this task seems broader than the gap and is somewhat a restatement of the gap.
  - This task assesses emerging technologies. The SRP thinks it would make sense that this information is used either to possibly close some gaps based on new technology or to generate some new research tasks. It is not clear to the SRP who would be responsible for doing that with the information received.

SHFE-HCI-05: We need verifiable requirements that specify standard measurement techniques and metrics for evaluating the quality of user interfaces with specific attention to the usability and evolvability of an interface.

- The gap for SHFE-HCI-05 is foundational, with many other targets dependent on it. The target is defined well-enough to begin but will probably need to be revised as more is learned.
- The SRP would like to know the definition of "evolvability of a user interface".
- The SRP thinks that there needs to be more clarity about verification vs. validation.

The SRP recommends following the distinction proposed by Jarke, et al (2011) that Validation focuses on what the system should do, independently of how it does it. Verification confirms that how it does it works. (Jarke, M., Loucopoulos, P., Lyytinen, K., Mylopoulos, J., Robinson, W. (2011). The brave new world of design requirements. *Information Systems 36* (7), pp. 992–1008).

- The operational definition of "verifiable" should be clarified. For example, a requirement has been verified when by meeting the requirement, human performance can be conducted with minimal or acceptable risk.
- The SRP recommends restating the interim steps as questions (as in SHFE-HCI-01).

Tasks:

- Usability Evaluation – PI: Aniko Sandor, Ph.D., NASA Johnson Space Center
- Human Factors Analysis Support Tool (H-FAST)– PI: Terence Andre, Ph.D., TiER1 Performance Solutions

The SRP thinks that both of these tasks are relevant, but not sufficient for the broad scope of verification or evolvability of an interface.

Proposed New Tasks:

- Investigate how valid requirements can be specified using ontology to define the required product of HCI work be added.
- Investigate how verification can be done on combined user procedures and machine procedures, by evaluating whether they satisfy a goal by effecting the needed change to the goal state of the ontology model. This task should feed into SHFE-HCI-08.
- Define and explain evolvability in the context of space missions.

SHFE-HCI-06: We need guidelines to ensure crewmembers receive all of the information required to accomplish necessary tasks in a timely fashion, even when operating autonomously.

- The SRP thinks that the interim steps for this gap should include a method for defining the information requirements ("…we do not know how to predict the type and level of information…") and then the information architecture.
- The SRP thinks that the target for SHFE-HCI-06 will provide important aspects of requirements for most other HCI tasks.

Tasks:

- Information Architecture for Exploration Missions – Planned task
  - The description of this task states that candidate architectures will be compared with respect to effectiveness, efficiency and satisfaction. The SRP thinks that this task may be able to determine if the information needed is able to be retrieved but not if users can do this effectively or efficiently. The SRP thinks that you will need a prototype user interface at the very least to do this and this will be very expensive if it has to be done for many different architectures.
- Information Integration for Electronic Procedures – Planned task

The SRP thinks that the tasks are relevant, but may not be sufficient to achieve the target.

Proposed New Tasks:

- Identify or develop the method for determining information requirements, such as information mapping to tasks.
- Validate the guidelines (SHFE-HCI-06 also notes that guidelines should be validated, but there does not seem to be a task doing this).

SHFE-HCI-07 (SM11): Can crewmember spatiomotor abilities be more accurately predicted and countermeasures and training techniques developed to mitigate spatial disorientation during spaceflight? (*This Gap has merged with HCI-03*)

Tasks:

- Enhancement of Spatial Orientation Capability of Astronauts on the Lunar Surface – PI: Rongxing (Ron) Li, Ph.D., The Ohio State University
- Modeling and Mitigating Spatial Disorientation in Low G Environments – Task completed

SHFE-HCI-08: We need to define the acceptable level of risk for HCI performance relative to terrestrial baselines.

- The SRP thinks that the target for closing this gap (board approval of levels of performance risk) seems too subjective. Rather, for any level of performance degradation that is proposed to be acceptable, some scientific justification should be sought and provided (e.g., performance is similarly degraded in combat, in previous space missions, in extreme environmental conditions, analogous to long-duration space missions).
- The SRP thinks that the target for this gap is more of an administrative objective and does not give enough guidance to define a technical approach.
- The SRP recommends adopting a generic design model of HCI that defines the various parts of factors and artifacts of design, to include:
  - The product of distributed cognition that results from HCI work
  - The allocation of functions between human(s) and machine(s)
  - Information architecture
  - User procedures and machine procedures
  - How the performance of procedures is constrained by logistical, organizational, and computational context
  - How cognitive architecture constrains user procedures
  - How the user interface constrains and enables user procedures

Some likely generic design models:

1. Dowell, J., & Long, J. (1989). Towards a conception for an engineering discipline of human factors. *Ergonomics, 32*, 1513-1535.
2. Butler, K. A., Zhang, J., Muehleisen, J., Hunt, A., & Huffer, B. (2010). Ontology models for interaction design: Case study of online support (4525-4540). *Proceedings of ACM CHI 2010 Conference on Human Factors in Computing Systems.*
3. Butler, K. A., Zhang, J. (2009). Design models for interactive problem-solving: context & ontology, representation & routines**.** *Proceedings of ACM CHI 2009 Conference on Human Factors in Computing Systems*

4. Ehrhart, L. & Sage, A. (2003). User Centered Systems Engineering Framework. In: H. Booher (ed.) *Handbook of Human Systems Integration*. Wiley.

Tasks:

- A Research Roadmap Approach to Defining the Risk of Inadequate HCI – Planned task
  - The SRP does not think there is enough stated about the task to evaluate it.

III. Discussion on the strengths and weaknesses of the IRP and identify remedies for the weaknesses, including answering these questions:

Is the Risk addressed in a comprehensive manner?

- The SRP thinks that there is a big improvement in the organization and process of a technology management strategy. There is still some confusion about interim steps, which should form a multi-task approach to achieve the target. The SRP thinks that the task granularity is uneven, but it is much easier to see key relationships to build towards a more effective technology roadmap.
- The SRP really likes the diagram that shows the various gaps and categorizes them as knowledge, mitigations, tech watch. The SRP is concerned about the timing of the tasks in the different areas so that dependent tasks get the information when it is needed. There are a number of places that have circular references. For example, the guidelines in SHFE-HCI-06 need to cover emerging technologies (SHFE-HCI-04), which could change over time requiring new guidelines to be developed.
- Performance is assessed by comparing ground and flight data with respect to mined data. The SRP is concerned about what will happen if there is no comparable task.

Are there obvious areas of potential integration across disciplines that are not addressed?

- The SRP is pleased with the integration. The SRP thinks that the SHFE Project realizes that HARI and HCI are very closely intertwined and so every instance in the research plan may not be specifically identified.

IV. Evaluation of the progress in the IRP Rev. D since the 2011 SRP meeting.

- The SRP thinks that there has been a large amount of progress on technology management strategy.
- The SRP likes having interim steps specified. This information provides the SRP a better sense of what is going to be done and how the information will be used.
- In previous years, function allocation was planned. The SRP is unclear where this is now.
- The SRP thinks that the organization of the SHFE review documents has improved significantly but still difficult to navigate. The SRP suggests task-mapping for clarity on which documents to refer to for which parts of the SRP process, how documents are

related to each other, and when there is overlapping content, which is most recent.

- It would be very useful to have an online, one-screen visual rendition of the risk, where at a glance, we could see all the tasks mapped to all the gaps, some visual indication of which are **NEW,** not started, in progress, or DONE; what tasks depend on others; funded, unfunded, or planned to be funded imminently; and whether they are running late, early, or on-time. Consider an enhanced Gantt or infographic.

V. Additional Comments

- The SRP thinks that the distinction between HCI and HARI should recognize that both may occur within a given system but at different times. For example, planning for a robotic mission may be an HCI task with a conceptual work product; then subsequently HARI would come into play as the mission is carried out with human supervision of the robot performing physical work. The distinction within the same system is that HCI took place earlier during the planning stage and affected the conceptual world, and then HARI took place during the execution of the plan in which a robot affects the physical world.
- The SRP thinks that some of the other gaps (as opposed to HCI-01) have multiple tasks that somehow have to be combined to answer an overall question. The SRP is unclear about who is responsible for ensuring that this happens.
- Each gap has interim steps defined and has attempted to define a measure for determining the closure of the gap. In most cases, it seems that gap closure results from the delivery of a product that is meant to reduce the risk of inadequate performance resulting from a particular condition (vibration, lack of proper knowledge, impacted cognition or attention, etc.). The SRP thinks that SHFE-HCI-08 sets the standard for this performance. Until that level is established and approved how will it be possible for gaps to be closed?
- The SRP thinks that the new model for managing technology is a lifecycle strategy that identifies gaps with targets for closure, metrics of closure, interim activities and task requirements. The new taxonomy of gap types seems very useful, but the SRP does not think it is consistent. Validating this new model on HCI is a good use for both its complexity and centrality and it has begun producing useful results. The new model for managing technology will be even better if more consistent terminology is adopted for naming gaps and relating interim steps and tasks to them. In some well-written gaps, such as SHFE-HCI-01, the interim steps seem like a series of questions that actually establish the technical approach that the tasks should carry out. If that is accurate then SHFE should review tasks in that context; i.e., SHFE should answer:
    - "Have the proper target for gap closure been defined, and are the technical approach and measures sufficient to hit the target?
        - Are the tasks relevant to the technical approach?
        - Are other tasks needed to carry out the technical approach?"

VI. Space Human Factors Engineering SRP Research Plan Review (WebEx): Statement of Task for the Risk of Inadequate Human-Computer Interaction

The 2012 Space Human Factors Engineering (SHFE) Standing Review Panel (SRP) is chartered by the Human Research Program (HRP) Chief Scientist. The purpose of the SRP is to review the SHFE Project section of the HRP's Integrated Research Plan, Revision D (IRP Rev. D) which is located on the Human Research Roadmap (HRR) website (http://humanresearchroadmap.nasa.gov/). Your report will be provided to the HRP Chief Scientist.

The 2012 SHFE SRP is charged (to the fullest extent practicable) to:

1. Evaluate the ability of the IRP Rev. D to satisfactorily address the Risk by answering the following questions:
   A. Have the proper Gaps been identified to address the Risk?
      i) Are all the Gaps relevant?
      ii) Are any Gaps missing? KAB- gaps need to reflect a meta-model of HCI

   B. Has the appropriate target for closure for the Gaps been identified?
      i) Are the interim stages appropriate to close the Gaps?

   C. Have the proper Tasks been identified to fill the Gaps?
      i) Are the Tasks relevant?
      ii) Are any Tasks missing?

2. Identify the strengths and weaknesses of the IRP Rev. D, *and* identify remedies for the weaknesses, including answering these questions:
   A. Is the Risk addressed in a comprehensive manner?
   B. Are there obvious areas of potential integration across disciplines that are not addressed?

3. Please evaluate the progress in the IRP Rev. D since your 2011 SRP meeting.

4. Please comment on any important issues that are not covered in #1, #2, or #3 above. If a charge addendum is provided, please address each of the questions as fully as possible.

Additional Information Regarding This Review:

1. Expect to receive review materials at least four weeks prior to the WebEx conference call.

2. Participate in a WebEx conference call on November 16, 2012.
   A. Discuss the 2012 SHFE SRP Statement of Task and address questions about the SRP process.
   B. Receive presentations from the SHFH Element.
   C. Participate in a question and answers session.

D. Attend Element or Project presentations, question and answer session, and briefing.

3. Prepare a draft final report (within one month of the WebEx/teleconference) that contains a detailed evaluation of the current IRP specifically addressing items #1, #2, #3, and #4 of the SRP charge. The draft final report will be sent to the HRP Chief Scientist and he will forward it to the appropriate Element for their review. The SHFH Element and the HRP Chief Scientist will have 10 business days to review the draft final report and identify any misunderstandings or errors of fact and then provide official feedback to the SRP. The SRP will have 10 business days to address any issues and finalize the 2012 SRP Final Report. The 2012 SRP Final Report will be submitted to the HRP Chief Scientist and copies will be provided to the SHFH Element and also made available to the other HRP Elements. The 2012 SRP Final Report will be made available on the Human Research Roadmap public website (http://humanresearchroadmap.nasa.gov/).

VII. Space Human Factors Engineering SRP Research Plan Review WebEx/Teleconference Participants

SRP Members:
Anna Wichansky, Ph.D. (Chair) – Oracle
Norman Badler, Ph.D. – University of Pennsylvania
Keith Butler, Ph.D. – University of Washington
Patricia DeLucia, Ph.D. – Texas Tech University
Jean Scholtz, Ph.D. – Battelle Memorial Institute
Randall Shumaker, Ph.D. – University of Central Florida

NASA Ames Research Center (ARC):
Mary Kaiser, Ph.D.

NASA Johnson Space Center (JSC):
Erin Connell, Ph.D.
Kritina Holden, Ph.D.
Craig Kundrot, Ph.D.
Susan Steinberg, Ph.D.
Thomas Sullivan, Ph.D.
Mihriban Whitmore, Ph.D.
Barbara Woolford

NASA Research and Education Support Services (NRESS):
Tiffin Ross-Shepard

VIII. Space Human Factors Engineering Standing Review Panel Roster

Panel Chair:

Anna Wichansky, Ph.D.
Oracle
Oracle Usability Advisory Board
500 Oracle Parkway-MS 3op3
Redwood Shores, CA 94065
Ph: 650-506-8007
Email: anna.wichansky@oracle.com

Panel Members:

Norman Badler, Ph.D.
University of Pennsylvania
Department of Computer and Information Science
3330 Walnut Street
Philadelphia, PA 19104-6389
Ph: 215-888-5862
Email: badler@seas.upenn.edu

Keith Butler, Ph.D.
University of Washington
Human Centered Design & Engineering
College of Engineering
423 Sieg Hall
Box 352315
Seattle, WA 98195-2195
Ph: 206-329-1981
Email: keith.a.butler@gmail.com

Patricia DeLucia, Ph.D.
Texas Tech University
Psychology Department
Boston Ave and 18th Street
Lubbock, TX 79409-2051
Ph: 806-742-3711 x259
Email: pat.delucia@ttu.edu

Jean Scholtz, Ph.D.
Battelle Memorial Institute
National Security/Information Analysis
340 Northslope Way
Rockaway Beach, OR 97136
Ph: 503-355-2792
Email: jean.scholtz@mindspring.com

Randall Shumaker, Ph.D.
University of Central Florida
Institute for Simulation and Training
3100 Technology Parkway
Orlando, FL 32826
Ph: 407-882-1301
Email: Shumaker@ist.ucf.edu